A STUDY OF H II REGIONS AND M8

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ABSTRACT

This paper will present an overview of the objects in the interstellar medium known as H II regions. These clouds of dust and gas are detected in emission throughout the plane of the galaxy, and are the site of ongoing star formation. Included is imagery of one of the more famous H II regions, M8, the Lagoon Nebula. The ionization structure of the nebula is examined and our ground-based imagery is compared to HST (Hubble Space Telescope) archival images of this object.

INTRODUCTION

The results of a study of the H II region, M8, are given. A group of eight students spent the months of June and July 1999 as part of an undergraduate research program in astrophysics at South Carolina State University (SCSU). NASA/MU-SPIN funded this project through the Network Resource and Training Sites (NRTS) at SCSU and at the City College of New York. During this time we used data taken in June 1994 at the San Pedro Matir (SPM) observatory in Baja, Mexico. The summer program at SCSU included an overview of astronomy and the physics of gaseous, emission nebulae. We used UNIX workstations and astrophysical image-processing software to reduce the images from SPM.

This paper begins with a discussion of the basic atomic processes that occur in such nebulae, including M8. Then what follows is a discussion of H II regions in general, what they are and how they form and evolve. Finally, the Lagoon Nebula is discussed as well as our own data analysis and results, which will be used by future investigators.

THE ATOMIC PROCESSES

In interstellar space, a cloud must be hot in order to emit visible light and so such clouds need a source of heat. Hot, blue stars are especially effective at heating because they emit large amounts of ultraviolet radiation whose short wavelength is much more energetic than that of visible light. When a hot, energetic star is embedded in such a cloud, one or more of the following occurs:

- **Ionization** - Ultraviolet radiation from the star ionizes the hydrogen in the gas, converting it into a plasma of positive hydrogen ions (protons) and free electrons. These detached protons and electrons then become part of the gas, each of them moving around as free particles.

- **Recombination** - The protons in the gas are continually colliding with electrons and recapturing them, becoming neutral hydrogen again. The electron falls through the various energy levels of the hydrogen atom on its way to the ground state, emitting a photon for each jump to a lower energy level closer to the nucleus of the atom.

- **Excitation** - An electron is not captured but, instead, collides with an ion. In doing so, the electron gives up some of its kinetic energy to the ion, thereby exciting it to a higher state of energy.

- **Deexcitation** – This can occur in one of two ways:
  - As an ion deexcites by way of collision, the original electron that caused the collision takes away energy from the ion and moves freely about. No photon is emitted.

- In the case of spontaneous decay, the ion itself drops to a lower energy level and, in this process, emits a photon.

It should be noted that as electrons cascade down through the various energy levels of the hydrogen atoms on their way to the ground states, they emit light in the form of emission lines. After an atom has captured an electron and emitted light, it loses that electron again almost immediately by the subsequent absorption of another ultraviolet photon from the star. Thus, although neutral hydrogen absorbs and emits light in H II regions, almost all hydrogen, at any given time, is in the ionized state.

H II Regions, An Overview

- H II regions are zones of gas that is mostly ionized.

- The II in H II refers to the second state of hydrogen, the ionized state.

- Gas temperature ~ 10,000 K (range from 7,000 to 12,000 K).

- Gas density ranges from 100 to 10,000 particles/cm^3. If the gas density is reasonably uniform, the ultraviolet radiation from the central star ionizes all the hydrogen in a roughly spherical volume of space. H II regions, however, are rarely spherical because the interstellar gas is clumpy.

- Includes several bright, hot stars responsible for ionizing the surrounding gas. Region typically appears red as it glows with the photons emitted when the electrons within the region recombine with hydrogen protons. The red color is largely due to the Hα photon at 6563 Å.

- H II regions are maintained by the continuous cycle of ionization of H I atoms (neutral hydrogen) followed by recombination of the H II ion. The central star of the nebula supplies the ultraviolet photons, which start the cycle.

FORMATION AND EVOLUTION

The Danish astronomer B. Strömgren developed the theory of H II regions, in 1939. In this theory, the life of an H II region can be divided into three stages:

- **Formation Phase** - begins with the main sequence turn-on of a type O or early type B star emitting a sufficient amount of ultraviolet radiation. The outflow of radiation from the star forms an ionization front (IF), which heats and ionizes the gas as it progresses outward. The formation phase comes to an end when the ionization front reaches the end of the Strömgren sphere, the point where the radiation field runs out of hydrogen-ionizing photons.

- **Expansion Phase** - the nebula and surrounding neutral material divide into distinct regions. These are identified as: the ionized gas inside the Strömgren radius; the ionization front; a shell of neutral material which has already been shocked but not yet ionized; the shock front; and the neutral molecular cloud. The expansion of the ionized zone continues because of a pressure differential between the compressed neutral zone and the ionized gas. The higher pressure in the ionized zone is due to the higher temperature and the larger particle density, since every ionization doubles the number of particles in the H^+ zone.

- **Recombination Phase** - reached when an approximate balance in pressure is attained on both sides of the ionized front. This occurs when either the Strömgren radius is so large that the radiation field is depleted of ionizing photons or the central star of the H II region evolves off the main sequence and the number of ionizing photons produced drops significantly. An equilibrium Strömgren sphere results.

The Lagoon Nebula

The Lagoon Nebula is one of the most spectacular examples of an emission nebula discovered to date. Located in the summer's night sky, the Lagoon Nebula can be viewed through binoculars in the constellation of Sagittarius. Named "Lagoon" for the bound of dust seeming to cut through its center (giving the appearance that the nebula is split in two) this nebula is home to a diverse array of astronomical objects, including a bright open cluster of stars and several energetic star-forming regions. The nebula itself is a large bubble of gas and dust set against the backdrop of an immense, ill-defined molecular cloud. Its general red glow is caused by luminous hydrogen gas, while the dark filaments are caused by absorption by dense lanes of dust. Also known as M8 and NGC 6523, the Lagoon Nebula lies approximately 4500 light-years away with a diameter of 120 light-years.

The large, majestic Lagoon Nebula is home for many young stars and hot gas, and is commonly referred to as a star factory. This star factory continues to eat away at the gas, all the while adding young, hot stars to the cluster. You can plainly see one of the factory's byproducts in NGC 6530, a visible group of stars on the eastern edge of the nebula.

At the heart of the Lagoon Nebula in Sagittarius is located the distinctive feature of the dumbbell-shaped, bright knot of gas and dust known as the Hourglass Nebula. The nearby star Herschel 36 powers this intense region, the 9th magnitude O7 star located in a small dark cloud just west of the Hourglass. The brightest star in the field of the Hourglass is the 6th magnitude 9 Sagittarii, a hot O5 star that appears to be the main illuminating source within the nebula.

SUMMARY

- The four major atomic processes, which occur in gaseous nebulae, have been studied and understood.
- The formation and evolution of H II regions is explained and represented figuratively.
- New ground-based imagery of M8 has been reduced and a preliminary analysis was made.
- A comparison was made between our ground-based images and one archival image of M8 taken by the Hubble Space Telescope.

CONCLUSION

Interstellar gas and, hence, H II regions play a crucial role in our galaxy. It is the material from which stars form, and it is the repository of matter blown off dying stars. Without interstellar matter to make new stars to replace those that die, the Milky Way would be dark and filled only with stellar corpses. And, on a personal note, interstellar gas creates some of the most spectacular structures in our galaxy – allowing us to mix business with pleasure.

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